U. S. Department of Agriculture
Natural Resources Service

TECHNICAL NOTES

STATE OFFICE STILLWATER, OKLAHOMA 74074

ECOLOGICAL SCIENCES TECHNICAL REFERENCES FOR IN-SERVICE USE ONLY

AGRONOMY OK-3 May 1, 1999

RE: NITROGEN AND PHOSPHORUS IN AGRICULTURE

Nitrogen (N) and phosphorus (P) are the major elements of concern when applying animal manures. Nitrogen is very mobile in the environment because it is volatile and water soluble, particularly as it oxidizes to nitrates. Phosphorus on the other hand, readily attaches to soil particles, is non-volatile and relatively immobile. For these reasons, maximum application rates for P have been established based on the soil's capacity to assimilate P. Nitrogen application is determined by the agronomic needs of the selected crop. Potassium is seldom identified as a problem.

The Waste Utilization (633) Standard and Specification details specific rates and is used when P is applied to the land in excess of that needed for plant growth. The Nutrient Management (590) Standard and Specification is used to detail agronomic application rates. Both these specifications reflect present research and will be changed as new research is available.

PHOSPHORUS (P)

Groundwater is normally of little concern in P considerations. However, there have been cases where dissolved P has been observed in groundwater. These are usually associated with thin layers of sandy soils, low in clay, overlying permeable aquifers (such as gravels).

Phosphorus is not directly toxic to humans. It becomes a concern when it enters water bodies and stimulates excessive undesirable aquatic plant growth that results in eutrophication. It is expensive to remediate the color, sediment, odor and taste problems caused by eutrophic conditions in drinking water.

Oxygen depletion occurs as a result of die-off and decomposition of excessive plant growth. Phosphorus is generally a limiting nutrient in fresh water systems and any increase in P usually results in more aquatic vegetation and algal blooms.

Phosphorus movement in runoff occurs primarily as particulate P and in extreme cases dissolved P. It is a complex interplay within the soil. Particulate P is attached to the mineral and organic sediment as it moves with the runoff. Dissolved P is in the water solution. Of the two, dissolved P is a much smaller proportion than particulate P.

Phosphorus binds most readily with the clay fraction, carbonates and organic matter of the soil. Clay content and pH are major controlling factors with P assimilation. As clay content, pH and organic matter increase, the P adsorption increases accordingly. Therefore, erosion control is the biggest concern in minimizing particulate P losses from agricultural land. This is not necessarily the case with dissolved P losses. Runoff control practices along with erosion control practices must be used to limit soluble P losses.

The percentage of dissolved P in the runoff increases with the P index in the soil. Research indicates that once the soil test P index reaches about 300, the amount of dissolved P loss is of water quality concern. However, P can be a concern anytime there are erosion problems.

Significant amounts of phosphorus can be lost in runoff from surface applied waste. Therefore, wastes that are injected or immediately incorporated after application, reduce the risk of loss. There are also differences between cultivated land and grasslands in how P is lost. On cultivated land, 75-90 percent of the P transported in the runoff is particulate P attached to sediment. From pastureland and reduced tillage systems, dissolved P composes the larger portion of the P in runoff.

Particulate P is less available for algae and plant uptake than dissolved P because of it's chemical bonding with mineral (particularly iron, aluminum and calcium) and organic compounds. Of course, it may become dissolved at a later date due to mechanical or biological action. Dissolved P is 100% available to plants and algae.

For simplicity, we have assumed soil test P is the primary source of P for plant uptake. Soil test P includes the solution P.

Below are some generalizations related to phosphorus

- Only 20% of P at application time is water soluble, depending upon the source.
- P cycles in water bodies through lake turn-over, sedimentation, algal blooms or high winds.
- P cycles seasonally through aquatic food chains.
- 95% of the P losses occur from surface applied wastes the first rain after P application, if it is of high intensity.
- Plant residues, fertilizer, wildlife and poor sanitation systems are also a source of P in addition to animal wastes.
- With repeated application, the P index in the soil increases. As the P level increases, losses during rainfall events increase proportionally because of poor adsorption.
- There is little migration of P below one foot.
- Light discing has little effect on adsorption of P.
- 4 to 10 lbs. Of P205 needs to be applied to get a I lb increase in soil test P.
- Most of the available P is adsorbed within 10 days of application except when applied above saturation levels.
- Grazing recycles most of the P in the pasture.
- Plants only contain about 0.2% P in the harvested material, depending on the soils and plants. Therefore, plant removal is not a significant factor in reducing P levels in the soil in the short term. Several years will be required for any significant depletion.
- Soil test P of 300 results in approximately one ppm P in the runoff.
- Not all the applied P is available to plants the same year of application.
- Dissolved P is immediately available for uptake by algae.

Planning efforts with clients should recognize that long term applications of manure at rates higher than plant harvest removal will result in a gradual build-up of soil test P over time. The higher the amount of P in the soil, the greater the concern about P runoff losses.

NITROGEN (N)

Groundwater is of major importance where N is involved. Moreover, N can be toxic to animals and humans when consumed in drinking water by interfering with the blood's ability to carry oxygen.

Soil nitrogen occurs in three major forms, (1) organic N in humus, (2) ammonium N (NH4) and (3) nitrates N (N03). Most of the nitrogen is present as organic nitrogen in the soil organic matter. Normally, about 2-3 percent is mineralized by microorganisms each year into a plant available ammonium or nitrate form when soils are cultivated. Of these forms, the nitrate is more mobile. This is a complex process, dependent on temperature, moisture and other factors that is not easily predictable.

Not all forms of nitrogen are released during the first stages of decay. Approximately 98% of all the soil nitrogen is unavailable for plant uptake. This provides an important buffer against rapid changes in available nitrogen and plant stress.

When manure is added to soil, a portion is converted to humus. In this form, the elements are released slowly and can have a continuing beneficial effect on the soil for many years.

The major losses of nitrogen from soils is by harvesting non-legume crops. Other losses include volatilization of ammonia, volatilization of nitrous oxide (denitrification), or leaching of nitrates out of the root zone. This explains why only 50 to 75 percent of the applied nitrogen is actually found in the crop. These factors also reveal why soil test nitrogen figures can be erratic. Approximately half the organic matter in animal manures is mineralized the first year of application.

Here are some generalizations about nitrogen

- Soils become more acid from the hydrogen released during mineralization, at least temporarily. One pound of hydrogen is produced for every 14 pounds of nitrogen mineralized.
- Crop production removes significant amounts of nitrogen each year and eventually the system becomes depleted.
- Haying of native grass meadows results in a net loss of nitrogen to the system.
- Rainfall adds about 5-8 pounds per acre of nitrogen per year to the soil.
- Nitrogen reacts the same in the environment regardless of whether or not the source is commercial fertilizer, organic soil material or animal manures.
- The crude protein in plant material is 16 percent nitrogen.
- About 60 to 90 percent of the N ingested by grazing animals is voided in urine.
- Plant residues, fertilizer, wildlife, animal wastes and home sanitation systems also contribute nitrogen.
- Cultivation stimulates aerobic mineralization of N.

SOIL TESTING

Soil testing by producers is an important component of a waste management plan. Testing establishes benchmark levels of soil P and alerts them to a build-up over time. Soil test information allows producers to make long term decisions concerning future additions of manure to the soil.

The Animal Waste Management Field Handbook is an excellent tool for planning. However, as systems become operational, soil testing should be used both to establish benchmark levels and to monitor the trend in nutrient build-up. Testing of manure at the site of application will better reflect actual nutrients "in the ground" locally.

Soil tests for nitrogen are more useful when done over time due to variations in climate and mineralization rates. Any testing that reveals a high P Index from long term waste application would signal that there are high levels of organic nitrogen in the soil as well. Soils testing captures only the nitrate form of nitrogen (N03).

DIFFERENCES IN NRCS SPECIFICATIONS AND EPA GENERAL PERMIT REQUIREMENTS

The basis for all NRCS recommendations for animal waste utilization is the Waste Utilization (633) standard and specification in the Field Office Technical Guide. The FOTG guidance reflects that N is always based on plant uptake, whereas P is based on soil assimilation. It should be noted, that in some cases, N can be most restrictive. In those cases, N will be the key nutrient for planning. All CAFO operations covered by the Oklahoma Feedyards Act and administered through the Oklahoma Department of Agriculture, also use the Waste Utilization standard and specification.

By contrast, regardless of P205 levels, the Region 6 EPA regulations are based only on plant use nitrogen, a less restrictive approach. The only exception being CAFO's located within the watershed of water bodies designated as "outstanding resource waters" and/or "scenic rivers" in the Oklahoma Water Quality Standards. This involves watersheds in Adair, Cherokee, Delaware, Sequoyah, LeFlore and McCurtian Counties.

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